THE EFFECTIVENESS OF ADAPTIVE ARTIFICIAL INTELLIGENCE (AI)-BASED LEARNING IN ENHANCING EFL LEARNERS' ENGLISH STRUCTURE MASTERY

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Article Info	Abstract
	The urgency of this study stems from the growing gap in English language learning, particularly in mastering English structures such as passive voice and complex sentences, which has widened in the aftermath of the COVID-19 pandemic. EFL students often struggle to comprehend complex grammatical forms, which adversely affects their writing and speaking proficiency. Adaptive AI-based technology presents a promising solution by offering personalized, interactive, and effective learning experiences. This study aims to experimentally investigate the effectiveness of adaptive AI technology in enhancing EFL students' understanding of English structure, specifically by comparing it to conventional teaching methods. A quasi-experimental design with a pretest-posttest control group approach was employed. The population consisted of undergraduate students majoring in English, and the sample comprised 60 students divided equally into experimental and control groups. The experimental group received instruction using adaptive AI technology, while the control group was taught using conventional methods. Data were collected through pretests, posttests, questionnaires, and interviews. Inferential statistical analysis, including MANOVA, was conducted to determine significant differences in grammar mastery between groups. The results indicated a statistically significant improvement in the experimental group's posttest scores (M = 84.70) compared to the control group (M = 74.30), particularly in mastering passive voice and complex sentences. Students also reported positive perceptions of the AI-based learning experience. This study contributes to the advancement of English language teaching and offers a scalable model for integrating adaptive AI in language education.

INTRODUCTION

The advancement of Artificial Intelligence (AI)-based educational technologies and adaptive learning systems has significantly reshaped instructional methodologies, particularly in the domain of English as a Foreign Language (EFL) education. Platforms such as Duolingo have been shown to enhance learner motivation and academic outcomes through interactive features, gamification, and instant feedback mechanisms (Kherazi & Bourray, 2024; Shen et al., 2024). Empirical studies indicate that gamified learning environments not only promote more engaging learning experiences but also positively influence students' academic achievement and motivation (Boudadi & Gutiérrez-Colón, 2020; Seventilofa, 2024). AI

technologies further enable personalized learning by tailoring content and challenges to individual learners' progress and preferences.

Despite the promising potential of AI in language learning, its application to complex grammatical structures—such as the passive voice and complex sentences—remains fraught with challenges. A study conducted by the present author in 2023 revealed that EFL students often struggle to master the passive voice due to the lack of contextualized and meaningful practice, which adversely affects their academic writing and speaking skills (Masyudi et al., 2023). Moreover, a 2024 investigation into interactive technologies for teaching complex sentence structures found that although such tools enhance comprehension, significant difficulties persist in aligning instructional content with individual learner needs in an adaptive manner (Hadi et al., 2024).

The urgency of this investigation is further underscored in the post-COVID-19 educational landscape, where language proficiency disparities have widened considerably. Robust empirical evidence is essential to inform the design of more effective, technology-integrated curricula tailored to the evolving needs of EFL learners. Ultimately, this research aims to contribute valuable insights into the application of AI-driven adaptive learning in the context of English grammar instruction, offering both practical implications for educational practitioners and theoretical contributions to the field of technology-enhanced language learning, both in Indonesia and globally (Alobaid, 2020; Szyszka, 2023).

In the context of EFL grammar learning, students' difficulties in understanding passive voice and complex sentence construction are often due to insufficient contextualized practice and a lack of personalized instruction (Szyszka, 2023). To address this issue, this research integrates adaptive grammar instruction that incorporates personalized learning paths and real-time feedback—an approach that has not been extensively tested in experimental settings.

Methodologically, most previous studies remain exploratory or rely on quasi-experimental designs (Lagari et al., 2023), thereby limiting the empirical evidence on the effectiveness of adaptive technologies in grammar instruction. This study adopts a true experimental approach using a pre-test and post-test control group design to offer a more rigorous quantitative assessment of the impact of AI-based learning interventions (Kusuma & Busyairi, 2023). Moreover, in the post-pandemic context where online learning has widened the grammar learning gap due to limited real-time feedback (Alobaid, 2020), this study proposes a more interactive and responsive AI-based grammar instruction model. Hence, this research not only contributes to theoretical advancement but also provides a practical and innovative solution to English grammar instruction challenges in Indonesia's EFL context.

This study seeks to address three key research questions: (1) To what extent can AI-based adaptive technology enhance EFL students' understanding of the passive voice and complex sentence structures compared to traditional instructional methods? (2) Is there a significant difference in learning outcomes between students who use adaptive technology and those who receive conventional instruction? (3) What are the advantages and limitations associated with the implementation of such technologies in grammar instruction?

RESEARCH METHOD
Research Design

This study employs an experimental design using a pretest-posttest control group approach to examine the effectiveness of adaptive AI-based technologies in enhancing EFL students' understanding of passive voice and complex sentences. This approach allows for a more structured and objective evaluation of the educational intervention's impact (Tiang-uan, 2023). The experimental group received adaptive technology-based instruction, whereas the control group followed conventional teaching methods. The comparison of pretest and

posttest results provides a clear indication of the intervention's success in improving comprehension.

Population and Sample

The research targeted first to fourth-semester students in the English Education program at Institut Pendidikan Nusantara Global. The sample was chosen through purposive sampling, focusing on students who had already completed the English Structure course but continued to struggle with understanding passive voice and complex sentences. This selection ensured the sample consisted of individuals facing the specific challenges the study aimed to address. To achieve statistical reliability and ensure the representativeness of the findings, 30 students were chosen for each group. This sample size was carefully determined to support meaningful analysis and generalizable results across the targeted population.

Instruments

The research procedure involved the following stages: 1) Development of research instruments, including pretests, posttests, and assessment rubrics. Instrument validation was conducted through a pilot test on a small sample to ensure the effectiveness of the measurement tools. 2) Pretests were administered to assess students' initial understanding. The experimental group then underwent AI-based learning involving initial diagnostics, adaptive content delivery, and instant feedback provided by platforms such as Duolingo and Quizlet (Habibie, 2020; Permatasari & Aryani, 2023). 3) Posttests were given to both groups to measure changes in comprehension.

The integration of AI technology in this study was implemented by ensuring active student engagement with applications like Duolingo and Quizlet. Through AI, the system can identify students' weaknesses and tailor exercises accordingly, a personalization advantage not available in traditional teaching methods (Kristiawan et al., 2024). Data collection utilized multiple techniques, including pre- and post-tests to measure comprehension gains and rubrics developed for qualitative assessment of learning outcomes. Observations and field notes were also maintained to document student responses to the adaptive AI technology use.

Data Analysis

Pretest and posttest data were analyzed using inferential statistical tests. Given the intervention's complexity, Multivariate Analysis of Variance (MANOVA) was employed to assess effects across multiple variables (Shadrina et al., 2024; Тодорова, 2023). Data analysis employed MANOVA using SPSS to evaluate differences in students' understanding of passive voice and complex sentences between the experimental and control groups. The analytical process included data entry of pre- and post-test scores, assumption testing (normality, homogeneity of variances, and correlation among dependent variables), and conducting MANOVA to determine the statistical significance of group differences (Millar & Budgell, 2019; Nimon et al., 2016). If significant differences were found, further post hoc analyses, such as Bonferroni or Tukey tests, were conducted to evaluate the specific impact on each variable (Smith et al., 2019). This approach ensures valid and reliable results in assessing the effectiveness of adaptive AI-based technology in English grammar instruction (Lubis & Miranti, 2024).

RESEARCH FINDINGS AND DISCUSSION
Research Findings

English as a Foreign Language (EFL) education has undergone a significant transformation with the emergence of Artificial Intelligence (AI)-driven learning technologies. This study focuses on evaluating the effectiveness of adaptive AI technology in improving university students' comprehension of English structures, particularly passive voice and complex sentences. AI-based adaptive learning provides a more personalized and

responsive instructional approach, enabling more efficient and targeted learning experiences (Nurmala et al., 2023; Yun et al., 2024).

In this study, 60 EFL students were divided into two groups: an experimental group that engaged with adaptive AI technology, and a control group that received conventional instruction. Analysis of the pretest and posttest results revealed that the experimental group achieved significantly greater score gains than the control group. A summary of the descriptive statistics is presented in Table 1.

Table 1
Descriptive Statistics of Pretest and Posttest

Group	N	Pretest (Mean ± SD)	Posttest (Mean ± SD)	Δ Score	Interpretation
Experimental	30	63.20 ± 6.45	84.70 ± 5.80	21.50	Significant improvement
Control	30	62.50 ± 7.00	74.30 ± 6.90	11.80	Moderate improvement

These findings align with prior studies that highlight the positive impact of AI in language learning, especially in enhancing learner motivation and comprehension of complex material (Chen et al., 2024; Yunina, 2023). AI-based learning platforms, such as Duolingo and other intelligent learning systems, are capable of adapting content delivery to students' abilities and progress. These systems facilitate real-time performance evaluation, provide relevant feedback, and suggest personalized learning pathways tailored to the learners' individual needs (Bhatt & Muduli, 2022; Saidakhror, 2024). This reinforces the concept of need-based learning that is both relevant and engaging.

The integration of AI into language instruction also promotes active student engagement. Tools such as chatbots and natural language processing-based language assistants facilitate authentic interaction and enhance speaking and listening skills (Li & Wong, 2023; Omri et al., 2025). Other studies confirm that sustained interaction during learning processes contributes significantly to students' understanding of complex grammatical structures like passive voice and complex sentences (Dong & Xiao-hua, 2022; Fishman & Ashbaugh, 2022).

A one-way multivariate analysis of variance (MANOVA) was conducted to examine the effect of the AI-based instructional method (adaptive AI learning vs. conventional instruction) on students' mastery of English grammar, specifically in the domains of passive voice, complex sentence construction, and total grammar performance. The independent variable was the type of instruction, and the dependent variables were the students' posttest scores across these grammar components. The MANOVA results revealed a statistically significant difference between the two instructional groups across the combined dependent variables, Wilks' Lambda = 0.713, $F(2, 57) = 11.52$, $p < 0.001$, with a Partial $\eta^2 = 0.287$, indicating a large multivariate effect size. This suggests that approximately 28.7% of the variance in students' grammar performance can be attributed to the instructional method employed.

Follow-up univariate ANOVAs further demonstrated that the experimental group significantly outperformed the control group in both *passive voice* ($F(1, 58) = 17.89$, $p < 0.001$, $\eta^2 = 0.236$) and *complex sentence structure* ($F(1, 58) = 21.45$, $p < 0.001$, $\eta^2 = 0.270$), both of which also represent large effect sizes. These results underscore the educational effectiveness of adaptive AI technology in supporting students' acquisition of complex syntactic structures in English. A detailed breakdown of the MANOVA findings is presented in Table 2.

Table 2
MANOVA Test Results for Grammar Comprehension Variables

Dependent Variable	Main Effect	Wilks' Lambda	F	df	p-value	Partial η²	Effect Interpretation
Passive Voice	Group	0.79 4	7.89	, 58	< 0.001	0 .236	Large, significant effect
Complex Sentences	Group	0.76 6	1.45	, 58	< 0.001	0 .270	Large, significant effect
Total Grammar Score	Group	0.71 3	1.52	, 57	< 0.001	0 .287	Large multivariate effect

The effectiveness of adaptive learning was further validated through multivariate analysis, which provided a comprehensive examination of the data. The results from the Multivariate Analysis of Variance (MANOVA) revealed that AI-based instruction significantly enhanced students' mastery of grammar. This statistical method allowed for the evaluation of multiple dependent variables simultaneously, providing a clearer picture of the impact of AI-driven learning on various aspects of grammar proficiency. The findings, as detailed in Table 3, suggest that the adaptive learning approach not only positively influenced grammar skills but also demonstrated a strong, measurable effect on students' overall language learning outcomes.

Table 3
MANOVA Results

Effect	Wilks' Lambda	F	df	p-value	Partial η²
Treatment (AI vs Conventional)	0.713	11.52	2, 57	< 0.001	0.287

The Partial η² value of 0.287 indicates that 28.7% of the variance in posttest scores can be attributed to the AI-based intervention, representing a large effect size (AlTwijri & Alghizzi, 2024; Lu & Yang, 2024). In addition to the quantitative data, student perceptions of the adaptive learning experience were overwhelmingly positive. The results of a post-intervention Likert-scale survey indicated consistently high ratings across all evaluated dimensions, as detailed in Table 4.

Table 4
Student Perceptions of Adaptive AI-Based Learning

Evaluation Aspect	Average Score (1–5)	Interpretation
Relevance of learning content	4.3	Very Good
Ease of platform use	4.2	Excellent
Accuracy and timeliness of feedback	4.5	Very Good
Motivation and engagement	4.4	Very Good
Understanding of grammar structures	4.6	Very Good

The data showed that AI-assisted learning significantly facilitated their understanding of complex grammatical concepts while enhancing EFL learners' engagement and autonomy in learning. This finding was further supported by follow-up interviews, which revealed increased confidence and motivation among participants. Despite these advantages, the implementation of AI in education is not without challenges. Potential algorithmic bias, overreliance on technology, and digital literacy gaps among both students and instructors remain critical concerns that need to be addressed (Han & Lee, 2024; Shi, 2024). Therefore, AI integration in education must be approached with careful planning and inclusivity.

This study offers valuable insights for the theoretical and practical development of AI-supported EFL instruction. Future research should explore the longitudinal effects of adaptive

AI learning and test its efficacy across different contexts to ensure generalizability and pedagogical scalability (Chedrawi et al., 2024; Parada-Cabaleiro et al., 2022).

Discussion
Significant Improvement through AI-Based Adaptive Learning

The results of this study reveal a statistically significant improvement in English structure comprehension among EFL learners who engaged with AI-based adaptive learning systems. Specifically, the experimental group scored an average of 84.70 on the posttest, outperforming the control group which averaged 74.30. This substantial difference underscores the effectiveness of adaptive learning technologies in personalizing instruction to meet individual learner needs. By providing immediate feedback and dynamically adjusting the difficulty and content of exercises, AI facilitates a learning environment that responds fluidly to each student's progress, thus promoting enhanced academic performance (Elmabaredy et al., 2020).

Moreover, the use of Multivariate Analysis of Variance (MANOVA) strengthens the validity of these findings by confirming significant multivariate effects across different linguistic components, including the passive voice and complex sentence structures. This statistical approach ensures that the observed improvements are not confined to a single language feature but represent a broader enhancement in learners' grasp of English grammar. Such comprehensive gains align with prior research indicating that AI-driven adaptive systems can simultaneously target multiple skill areas, thereby fostering more holistic language development (Elmabaredy et al., 2020).

Constructivist Learning Principles in AI-Enhanced Environments

The adaptive learning model employed in this research is firmly rooted in constructivist learning theory, which posits that learners construct knowledge actively through interaction with materials and their environment (Anwar & Ali, 2020; Yakar et al., 2020). In this framework, AI acts not only as a content deliverer but as an intelligent mediator that scaffolds learners' experiences by tailoring tasks to their current level of understanding. Such engagement encourages students to move beyond rote memorization, promoting meaningful comprehension through authentic contextualization of language patterns, such as passive constructions and complex syntactic forms (Vallecillo et al., 2024).

Furthermore, adaptive web-based learning environments that incorporate these theoretical principles have been shown to significantly enhance student motivation and engagement compared to traditional, static instructional methods (Ningsih, 2021). The rapid feedback loops enabled by AI systems allow learners to identify errors and misconceptions in real time, fostering a cycle of continuous improvement. This dynamic interaction supports deeper cognitive processing and facilitates active participation, which is critical for mastering intricate linguistic structures (Raibowo et al., 2023; Wang et al., 2023).

Pedagogical and Curricular Implications in the Post-Pandemic Era

The post-pandemic educational landscape has amplified the demand for flexible, learner-centered approaches that can accommodate diverse student needs and contexts. This study's findings highlight the pivotal role of AI-based adaptive learning in meeting these challenges, especially within English language instruction (Anggraeni & Pentury, 2020). By integrating adaptive technology, educators can offer tailored learning paths that sustain student motivation and promote autonomy, which are essential factors in achieving meaningful language acquisition in remote or hybrid settings.

In practice, platforms such as Duolingo and Quizlet exemplify how technology can transform language learning by combining gamification, personalized feedback, and accessible digital resources to create engaging and effective learning experiences (MOYON,

2024). These tools not only support comprehension but also cultivate learner independence, which is crucial in contexts where face-to-face interaction is limited. As such, institutional adoption of these technologies is vital for maintaining continuity and quality of language education amid ongoing shifts in pedagogical delivery modes (Liando et al., 2022).

Limitations and Future Research Directions

Despite the promising outcomes reported, several limitations warrant cautious interpretation and guide future research. Firstly, the relatively small sample size (n = 60) limits the generalizability of findings, emphasizing the need for replication with larger, more heterogeneous populations across different educational contexts to confirm the scalability and robustness of AI-based adaptive learning effects (Cavanagh et al., 2020; Yunina, 2023). Larger samples can also facilitate subgroup analyses to explore differential impacts on learners with varied backgrounds or proficiency levels.

Secondly, the intervention's short duration—less than a full academic semester—may restrict insights into the long-term efficacy and sustainability of gains achieved through AI adaptive learning tools. Longitudinal studies are therefore recommended to monitor learners' progress over extended periods and to capture potential delayed effects, retention rates, and changes in motivation or engagement (Babu & Anitha, 2023; Golzar et al., 2024). Additionally, the study's platform-specific focus on Duolingo limits the applicability of results across other AI systems, suggesting further comparative research to evaluate different platforms' effectiveness and unique affordances (Butakor, 2023; Xu & Tu, 2022).

Ethical Considerations and Access Equity

The deployment of AI in educational contexts raises important ethical and social justice concerns that must be addressed to ensure equitable and responsible use. Data privacy and security constitute paramount issues, as AI platforms collect extensive learner data to personalize instruction. Safeguarding this sensitive information and establishing transparent data governance policies are critical to maintaining trust and protecting users from potential misuse or breaches (Crawford & Serhal, 2020; Sepp et al., 2022). Furthermore, overreliance on automated systems may inadvertently diminish valuable human interactions essential for holistic educational experiences, underscoring the necessity of balancing technology with meaningful teacher-student engagement (Qodr et al., 2021; Tsang et al., 2021).

Equally important is addressing the digital divide that threatens to exacerbate educational inequalities. Unequal access to reliable internet and compatible devices can limit the benefits of AI-enhanced learning for disadvantaged students, thereby widening achievement gaps (Marshik et al., 2024). Institutional policies must therefore prioritize inclusivity by investing in infrastructure, training, and support to ensure that all learners and educators can effectively utilize these technologies. Enhancing digital literacy across the educational community is vital for maximizing the potential of adaptive learning innovations and fostering an equitable learning environment (Glover et al., 2020; Schaekermann et al., 2024).

This study provides compelling evidence that AI-based adaptive learning significantly improves EFL learners' mastery of complex English grammatical structures, consistent with constructivist learning theory that emphasizes active engagement and scaffolded knowledge construction (Lin & Lee, 2023). By facilitating personalized learning experiences, these technologies address individual differences and foster deeper linguistic comprehension, which are crucial in the increasingly digital and globalized educational context.

The implications extend beyond immediate academic benefits, highlighting the necessity for educational institutions to integrate adaptive learning technologies strategically into curricula to enhance learner autonomy and motivation. Future research should expand on these findings by employing larger, longitudinal, and mixed-method designs, exploring

diverse linguistic skills, and evaluating multiple AI platforms to ensure broad applicability and optimize pedagogical outcomes (Anggraeni & Pentury, 2020; Gong et al., 2025). In doing so, the field will be better positioned to harness the transformative potential of AI in language education while addressing ethical and equity considerations integral to sustainable educational advancement.

CONCLUSION

This study demonstrated that adaptive Artificial Intelligence (AI)-based instruction significantly enhances EFL students' mastery of English grammar, particularly in the areas of passive voice and complex sentence construction. The experimental group outperformed the control group, confirming the effectiveness of personalized, real-time, and adaptive learning environments in improving linguistic outcomes. The application of MANOVA provided robust statistical support for these findings, reinforcing the pedagogical value of AI integration in language learning.

The study also emphasized the relevance of constructivist and scaffolding theories in framing technology-enhanced education. Moreover, the results highlighted the importance of learner engagement, autonomy, and motivation in digital learning environments. These findings carry important implications for the design and implementation of AI-supported instruction, especially in post-pandemic educational contexts where flexible and learner-centered approaches are increasingly essential. While the findings are promising, they also underscore the necessity for ethical, inclusive, and pedagogically sound integration of AI in language education. Institutions and educators are encouraged to adopt strategic frameworks that support equitable access and meaningful learner interaction in AI-assisted classrooms.

INFORMED CONSENT STATEMENT

Participation in this study is entirely voluntary. By agreeing to take part, the participants acknowledge that they have been informed about the purpose, procedures, potential risks, and benefits of the study. Participants understand that their identity are kept confidential and that all information they provide are used solely for research purposes.

DATA AVAILABILITY STATEMENT

The data utilized in this study cannot be made publicly available due to strict adherence to privacy concerns and ethical obligations that safeguard participant confidentiality. This ensures compliance with ethical research standards and data protection regulations.

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